TRANSACTIONS
OF
American Microscopical Society
(Published in Quarterly Installments)

Vol. XXXVI JANUARY, 1917 No. 1

DEPARTMENT OF SUMMARIES

TO BE DEVOTED TO DIGESTS OF PROGRESS IN BIOLOGY

While the *Transactions* will continue to be primarily a Journal of research in micro-biology, it is recognized that the field has become so broad as to preclude the possibility of frequent articles in any one of the departments of special interest. Because of this it will be the policy to present, from time to time, supplementary digests of the progress being made in the various fields of micro-biology. It is also proposed to introduce similar summaries of the progress made in some departments not represented in our articles of research. This is done with the feeling that such reviews will increase the permanent value of the *Transactions* to all who may not have access to a large list of technical biological journals, nor the time to make the survey for themselves.

BACTERIOLOGY IN PLANT PATHOLOGY

By F. L. Stevens

It is my purpose to direct your attention to the place and importance of bacteriology in the field of plant pathology, from the standpoint of North American students and investigators, and to summarize briefly the progress during the comparatively brief interval since the inception of this science. I shall first consider the subject in its broader, general aspects, then in its more special relations.

It was inevitable that the brilliant results of the early workers in bacteriology, especially as regards fermentations and animal pathology, should direct the attention of plant pathologists to bacteria as a possible source of solution of some of their own problems.

Thus, in the year 1877 we find Dr. Burrill saying regarding pear blight. "The cambium of the blighted branch, when the trouble first shows itself, and for some days thereafter, is filled with minute moving particles.

"Not unfrequently, a thickish, brownish, sticky matter exudes from affected limbs, sometimes so abundant as to run down the surface or drop from the tree. This proves to be identical with that noticed in the cambium, and unquestionably has the same origin. The sticky, half-fluid substance thus exuding is entirely made up of these minute oscillating particles." Transactions Illinois Horticultural Society, 1877, page 114.

In 1878 he said—"If we remove the bark of a newly-affected limb, and place a little of the mucilaginous fluid from the brown tissues under our microscope, the field is seen to be alive with moving atoms known in a general way as *bacteria.* Sometimes a thick, brownish fluid oozes from the bark of dying limbs and spreads over the outside or falls in drops. This is apparently made up of living things, myriads of them to be seen at once. A particle of this viscous fluid introduced upon the point of a knife into the bark of a healthy tree is in many cases followed by blight of the part, but with me not in every instance." Transactions Illinois Horticultural Society, 1878, page 80.

In 1881 he said: "But of the pear trees inoculated by budding and puncturing, as described, *sixty-three percent became diseased,* exhibiting all the characteristics, externally and internally, of the blight.

"Less than two percent of those not inoculated became infected with the disease.

"The slight wounds made by the process of inoculation cannot be charged with the results, for similar wounds were made with a clean needle, and these rapidly healed without further injury. *The introduction of the virus introduced the cause of the disease, and the potency of the virus was quite positively due to the living bacteria."* Blight of Pear and Apple Trees: 10th Report Board of Trustees Ill. Ind. Univ., 69, 1881.

In American Naturalist, Vol. 15: p. 527, we find: "Certain diseases of animals are now positively known to be due to the action of the minute organisms commonly known as bacteria, but it has not been shown that they also cause disease and death of plants, except as recently announced by the writer in case of 'blight' in pear and apple trees.

"In 1877 I observed in the fluids of blighting pear trees, great numbers of minute, moving things which were not clearly identified as bacteria until the following year. Their presence was uniformly detected in every examination made (and they were numerous) during the summer of 1878, and the fact was reported to the Illinois State Horticultural Society, in December of that year. Investigations were not further prosecuted until June, 1880, when the unusual prevalence of the disease called more special attention to it. The same organisms, or those very similar, were as uniformly found in the tissues of apple trees suffering with the disease called twig blight. On diseased parts of both trees, drops of whitish, viscid material were often found, oozing from the bark, and this proved to be almost wholly made up of the bacteria."

From the time of the early work of Dr. Burrill onward there has been a steady increase in the number of diseases suspected or known to be of bacterial origin.

In the early days, technique was undeveloped and many of the early hints at bacterial diseases were indeed barely hints. Many of the things described then are difficult or impossible of recognition now, while others have become the subjects of repeated research and knowledge of them has been clarified.

Here as elsewhere in science, fundamental battles were fought. In the period 1879 to 1892, many researches abroad and a few in America were directed to determine whether bacteria occur in normal, sound plant tissues with of course a final result in the negative.

Though numerous plant diseases were early attributed to bacteria (1877-1883) the number which received final acceptance as such grew slowly. The text books bearing upon the subject give only grudging credence. Even as late as 1892 only 13 plant diseases are given by Russell as of established bacterial origin with nine "Probably of bacterial origin." Marshall Ward, the English authority, in 1894 editorially doubts even the bacterial origin of pear blight. As late as 1897 Frank evinces doubt as to bacterial diseases in these words: "Whether bacteria can be the cause of disease in plants is always a question to be considered with circumspection." p. 201 Frank Kampfbuch. But the most vigorous attitude of denial was taken by Alfred Fischer in 1897 who held that

there are not and cannot be bacterial diseases of plants because bacteria cannot enter plants except through wounds and that their development then will be stopped by corky layers. "The *uninjured plant* stands in open connection with the outer world only through the stomata, which connection is so limited that the system of air-filled intercellular spaces connects with the outer world but is entirely closed to the cells. When bacterial germs are forced into the stomata by wind or rain, they here reach only into these intercellular spaces where nothing further is offered to them than vapor-saturated air, where all nutrient substances are wanting, without which no bacterial spore can germinate, no bacterial cell can multiply. All these peculiarities are wanting in the bacteria, against which an uninjured plant is fully protected. But also the *wounded plant* offers food for bacteria only in the opened, injured cells, a source which is soon removed by the formation under the wounded surface of an impenetrable cork layer (wound cork) which entirely prevents any further flow of sap from the wound. The wound does not remain moist, the injured cells shrivel and dry out, and consequently the entrance of the bacteria is exactly so barred out as in the uninjured plant. Consequently, there is not the least danger of wound infections by bacteria, whose further progress in the plant is also impossible." Translation by E. F. Smith, Bacterial Diseases of Plants II, p. 15.

Wehmer in 1898 assumed a similar viewpoint. The trend of *ex cathedra* opinion at this period toward the denial of the existence of bacterial plant diseases, in opposition to rapidly increasing evidence of their abundance, appears to us today as most remarkable. The controversy became crucial between Dr. Erwin F. Smith and Dr. Fischer, the latter asserting in 1899 that "there has not yet been published a single proof for bacterial plant disease which meets all the requirements of exact bacteriology. Smith in 1899 and 1901 in masterly articles adduced such complete evidence that since then his position has not been challenged. From that period to the present time very numerous bacterial plant diseases have been described in America and elsewhere until in 1915 we find more than 140 genera of host plants listed with something more than one hundred

bacterial forms suspected or proved to be responsible for certain of their diseases.

Owing to the difficulties and obscurities of the subject as compared with that of fungous diseases, it is probable that a large percentage has been as yet overlooked, indeed the rapid growth in number of descriptions of diseases of this class during the last few years is especially striking and betokens corresponding increase for some time to come.

In addition to mere listing and identification of the cause of the disease, fundamental progress has been made in the knowledge of the biological and ecological relations of the host and parasite.

The action of the parasite has by critical studies been shown to be through enzymes and in particular enzymes acting upon and dissolving the middle lamella and thus bringing about dissolution of the tissues.

A group of diseases of distinct type, the "wilts" are found to be largely, tho not exclusively bacterial, and are due to a plugging or embolism brought about by growth of bacteria within the vessels of the plant. Infection has been shown to occur in a variety of ways, notably through wounds which break down the outer protective plant coverings or what is perhaps much more remarkable, through natural openings such as stomata, water pores or nectaries.

Important contributions have been made upon the subject of infection carriers, more particularly since the role of certain insects in this regard has been ascertained with precision. Surface soil water is in some cases responsible for extensive distribution of the parasite. Continued growth and multiplication of parasitic bacteria in the fallen plant parts or even in the manure pile offers an additional explanation of disease dispersal in some instances. In other cases it has been demonstrated that the casual bacteria remain alive upon the outside of the seed coats and thus lead to infection of the ensuing crop.

Phytopathological bacterial studies have in several instances been conducted with such thoroughness that descriptive and taxonomic bacteriology have been distinctly enriched.

The bacteria involved in plant disease are preeminently of the genera Pseudomonas and Bacillus. The Cocci, Bacteria and Spirilli

so prominent in animal pathology sink to a very minor position, there being no Spirilli known as plant pathogens and very few of the genus Bacterium and still less of the genus Micrococcus.

The foregoing may serve to give a general impression of the history and activities of students of plant pathology within the field of bacteriology.

The following table shows most of the specific diseases that have commanded attention in North America.

A straight, uncrossed line ——, indicates the date of first knowledge of the bacterial nature of the disease, or in some instances of the species of bacteria which cause it. One cross mark —|—, indicates definite progress toward a cultural or morphological description, or both. Two cross marks —||—, indicate a rather comprehensive bacterial study. Three cross marks —|||—, indicate that quite complete bacterial study has been made. Two stars **, indicate that the disease is one of much importance in this country; one star *, that it is important but not of first rank. Those with no star are little known, or are of narrow geographic range or of little import. Numbers in the table refer to the bibliography in Stevens, "Fungi Which Cause Plant Disease," beginning on page 53. "a.b." indicates that reference may be found in the "Additional Bibliography" of the same work.

In general it is noted that very few bacterial diseases were known prior to 1886 but that from then onward there has been a steady increase in their number.

Studies in any way complete were very few prior to 1895 but became much more abundant after that time and the newly described diseases which take their places in our table in later years frequently first appear before us with details well worked out. In particular is this very satisfactory condition true within the last decade and a half.

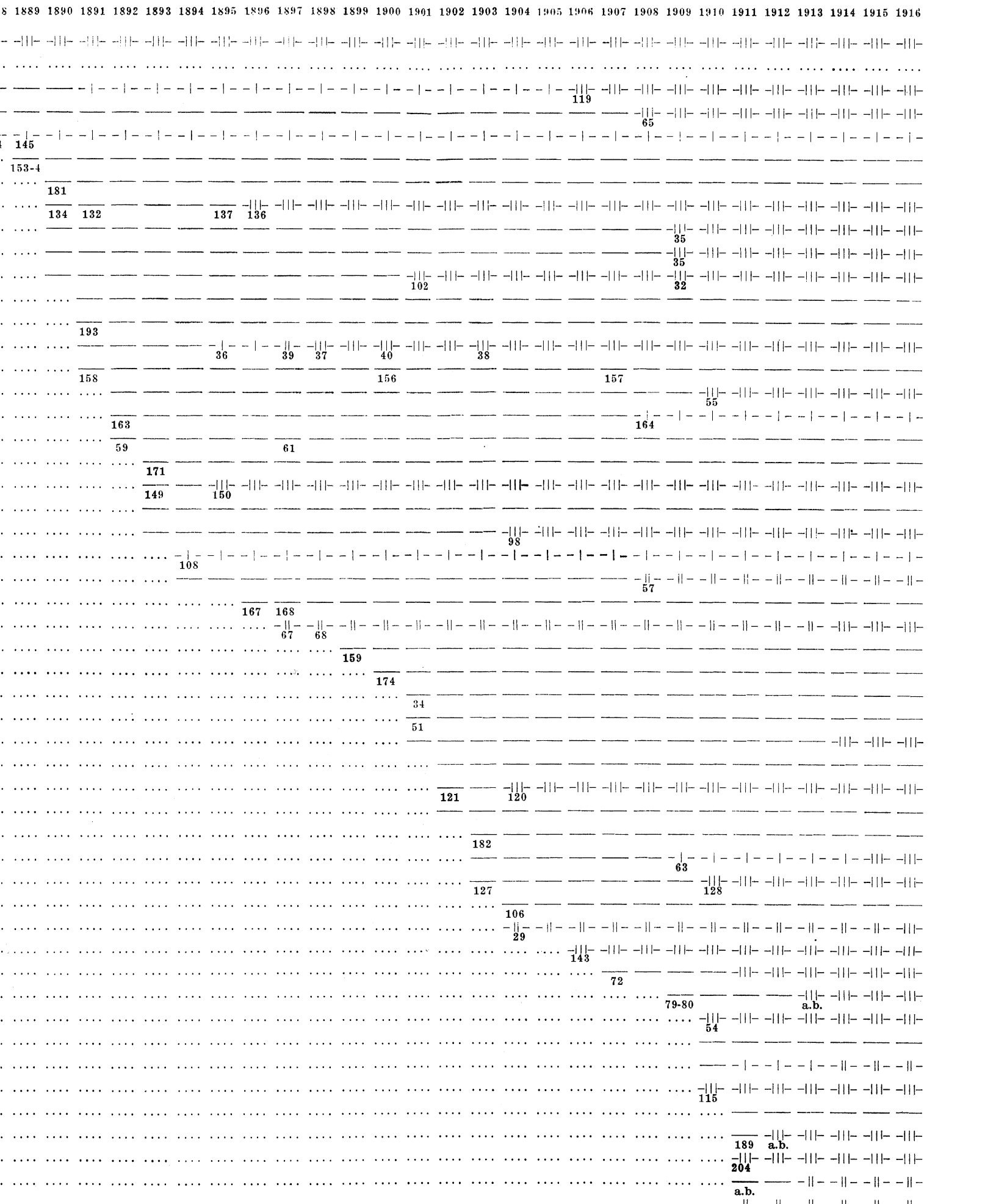
Time forbids discussion of these diseases, 64 in number on more than 70 hosts. A few however demand special mention.

Bacillus amylovorus, the cause of the pome blight is widespread and the cause of immense pecuniary loss.

Pseudomonas radicicola occupies the anomalous position of being a beneficial disease. The progress of knowledge concerning it is not indicated in the table.

TABLE SHOWING PROGRESS OF KNOWLEDGE CONCERNING AM

PARASITE		HOSTS	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893
B. amylovorus	XX	Pomes	82			84				85									
Ps. radicicola		Legumes																	
B. oleæ		Oleander, olive																	
Ps. savastanoi		Olive																	
B. sorghi		Sorghum												144	145				
B. zeæ		Corn													153-4				
?		Salsify														181			
Ps. solanacearum	XX	Solanaceæ														134	132		
Ps. avenæ	X	Oats																	
B. avenæ		Oats																	
B. catorovorus		Vegetables																	
?		Melon																	
?		Celery															193		
Ps. campestris	X	Crucifers																	
?		Geranium															158		
Bact. michiganense		Tomatoes																	
?		Lettuce																163	
Ps. phaseoli		Bean																59	
Micrococcus?		Calceolaria																	171
B. trachelphilus		Curcurbs																	149
?		Carnation																	
B. aroideæ		Calla																	
B. gossypini		Cotton																	
Ps. mori		Mulberry																	
Micrococcus?		Strawberry																	
Ps. stewartii	X	Corn																	
?		Onion																	
B. sp.		Tomato blosson end rot																	
Ps. malvacearum		Cotton																	
Ps. juglandis		Juglans																	
Ps. amaranthi		Amaranthus																	
?		Banana																	
B. oleracea		Crucifers																	
?		Rubiaceæ																	
Ps. woodsii		Carnation																	
Ps. pruni		Prunus																	
B. phytophthorus		Potato																	
B. delphini		Delphinium																	
Bact. teutlium		Beets																	
B. solanisaprus		Potato																	
Ps. tumefaciens	X	Many hosts																	
Ps. aptatum		Tropeolum, beet																	
Ps. medicaginis		Alfalfa																	
B. araliavorus		Ginseng																	
B. musæ		Banana																	
B. melonis		Muskmelon																	
Ps. andropogoni		Broom corn																	
B. coli		Cocoanut, onion																	
Ps. maculicolum		Cauliflower																	
Ps. cerasus		Cherry																	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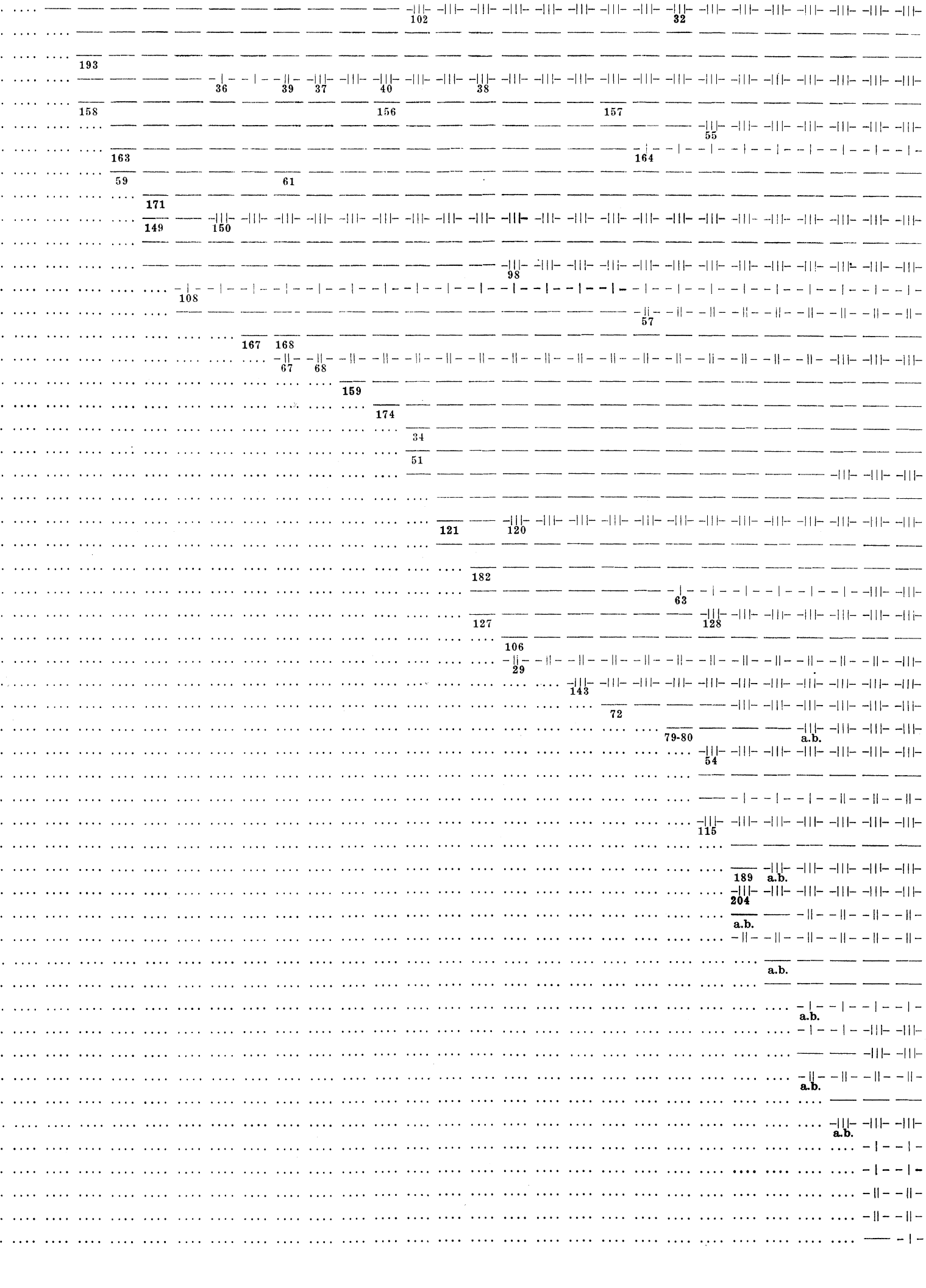
127
128
106
29
143
72
79-80
a.b.
54
115
189
a.b.
204
a.b.

B. catorovorus		Vegetables				
?		Melon				
?		Celery		193		
Ps. campestris	X	Crucifers				
?		Geranium		158		
Bact. michiganense		Tomatoes				
?		Lettuce			163	
Ps. phaseoli		Bean			59	
Micrococcus?		Calceolaria				171
B. tracheiphilus		Curcurbs				149
?		Carnation				
B. aroideæ		Calla				
B. gossypini		Cotton				
Ps. mori		Mulberry				
Micrococcus ?		Strawberry				
Ps. stewartii	X	Corn				
?		Onion				
B. sp.		Tomato blosson end rot				
Ps. malvacearum		Cotton				
Ps. juglandis		Juglans				
Ps. amaranthi		Amaranthus				
?		Banana				
B. oleracea		Crucifers				
?		Rubiaceæ				
Ps. woodsii		Carnation				
Ps. pruni		Prunus				
B. phytophthorus		Potato				
B. delphini		Delphinium				
Bact. teutlium		Beets				
B. solanisaprus		Potato				
Ps. tumefaciens	X	Many hosts				
Ps. aptatum		Tropeolum, beet				
Ps. medicaginis		Alfalfa				
B. araliavorus		Ginseng				
B. musæ		Banana				
B. melonis		Muskmelon				
Ps. andropogoni		Broom corn				
B. coli		Cocoanut, onion				
Ps. maculicolum		Cauliflower				
Ps. cerasus		Cherry				
Ps. beticola		Beet				
?		Pepper				
B. pyrocyanus		Begonia				
?		Cucumber				
Ps. lachrymans		Curcurbs				
B. lathyri		Sweet pea, clover				
Ps. citriputeale		Lemon				
?		Rose				
Ps. erodii		Erodium, geranium				
Ps. veridilivium		Lettuce				
Ps. citri		Citrus				
B. dianthi		Beet				
B. fluorescens (?)		Mushrooms				
Bact. agropyri		Agropyrum				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72
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189
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a.b.
a.b.
a.b.
a.b.

Pseudomonas solanacearum is very wide-spread and destructive as are also *Pseudomonas campestris* and *Bacillus tracheiphilus*. *Bacillus carotovorus* is the cause of soft rot of parenchyma on many hosts and the loss of much produce during storage.

The bacterial leaf galls of the Rubiaceæ, originally described by Zimmermann, are of particular interest as possible cases of symbiosis rather than parasitism.

Pseudomanos tumefaciens, the cause of crown gall on numerous hosts, has been shown by Dr. Smith and his assistants in a series of noteworthy investigations to furnish example of a here-to-fore unsuspected type of plant disease, in many respects analogous to human cancer. These investigations were prosecuted by overcoming great technical difficulties of staining and culturing and yielded results amazing from the viewpoint of anatomy and pathology and suggestive and stimulative of investigation relative to human cancer.

Bacillus avenæ with *Pseudomonas avenæ* presents an unique case of symbiosis in that the latter organism is, according to the work of Manns, much more productive of disease when accompanied by the former organism.

Bacillus coli as the cause of a very destructive bud rot of the cocoanut is especially interesting. One is loath to accept the conclusion but the work upon which it is based is well done. The experimental evidence is that the bud rot organism is in all ways indistinguishable from animal *Bacillus coli* and that *Bacillus coli* from animals will cause the typical rot. The case is still *sub judice*.

Pseudomonas citri is one of the latest to attract attention as the cause of the very serious Citrus canker which bid fair to make destructive inroads upon fruit culture in the Gulf states.

Several of the organisms or diseases listed above are so poorly described as to be unrecognizable, thus it is probable that some of these earlier ones are identical with those later listed as distinct and definitely described species.

As to practical results in the way of prevention, the situation is not so hopeful as in the case of diseases due to the Eumycetes. The value of the knowledge is that knowing the cause and perhaps the mode of hibernation and transmission, proper hygienic measures may be practiced. Dispersal upon seeds may be avoided by seed

treatment; dispersal by insects by combating the insects directly. Main sources of infection may be destroyed by fire, by the cutting and burning of diseased parts; distribution through the manure pile by care to avoid infecting the manure by diseased refuse.

In common with other fields of bacteriology there is need here of fundamental knowledge of the biology of bacteria, their variability, methods of classification, a stable system of nomenclature, of enyzmes, toxins, morbid histology, life histories, extra-parasitic existence, persistence in soil, agents of transmission, climatic relations. The way is long, the difficulties numerous. Much has been accomplished but much more remains to be done.

I cannot close this brief and manifestly inadequate presentation without paying especial tribute to the work of Dr. T. J. Burrill, the deceased president of this society and that of Dr. Erwin F. Smith, whose Treatise "Bacteria in Relation to Plant Disease" which though incomplete, already comprises three quarto volumes that are models of completeness; whose numerous single papers have enriched the world and whose careful judgment, and high standards of work and presentation have done much to influence the standards of all workers in this field.

(Read before the Society of American Bacteriologists at New Haven, Dec., 1916.)